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MECHANICAL ANALYSIS OF THE ROUNDHOUSE KICK ACCORDING TO THE STANCE POSITION. A PILOT STUDY

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In taekwondo combats, kick performance can be affected by the stance position. The aim of this study was to analyze mechanical variables in the roundhouse kick in taekwondo according to three stance positions (0º, 45º, 90º). Two high-level athletes participated in the study. Mechanical analysis was measured by two 3-D force plates and an eight-camera motion capture system. Data analyses were processed using Visual 3D software. From the 0º and 45º stance positions athletes kicked in less execution time and total response time than from the 90º stance position ($p < 0.05$). Moreover, the GRF predicted a high percentage of the variance of performance. Finally, the 0º and 45º stance positions seem more appropiate than the 90º stance position.

KEY WORDS: kinematic, ground reaction force, taekwondo, stance position.

INTRODUCTION: As a sprint start, the kick start is a complex motor task characterized by large forces exerted in different directions and by the ability to generate these forces in a short period of time (Fortier, Basset, Mbourou, Favérial & Teasdale, 2005). The adoption of the most suitable start position could be a key point in enhancing the performance of taekwondo athletes. In taekwondo combats, athletes can maintain offensive or defensive behaviour. Taking into account both options, athletes usually use a specific stance position that they feel more comfortable with. However, their stance position can also potentially affect their kick performance (Kim, Kwon, Yenuga & Kwon, 2010). Therefore, an in-depth study of kick performance according to these stance positions seems necessary.
There are three basic guard positions: one in which athletes approximately position their feet in an orthogonal direction (90º) with respect to the target; a second one in which athletes approximately position their feet in a diagonal direction (45º) with respect to the target; and lastly, one in which athletes position their feet oriented to the target (0º). The 0º stance position is less used since coaches and taekwondo athletes believe that this position does not allow for the development of correct spin kicks. Similar research in the field (Wang & Liu, 2002) showed the effect of two different guard positions on mechanical variables in karate. Specifically, they found that attacks in positions with a higher load on the front foot were made with faster movements than those with an equal load on both feet. Based on this, it seems that 90º stance positions are not as appropiate as 45º stance positions.
Studies in taekwondo have analyzed mechanical performance according to execution distance (i.e. Falco et al., 2009; Kim et al., 2010), and the athletes' competition level and gender (i.e. Estevan, Álvarez, Falco, Molina-García & Castillo, in press). However, to our knowledge, no studies have compared mechanical performance according to stance position in taekwondo. One of the aims of this paper was, therefore, to use these stance positions (0º, 45º, 90º) to compare mechanical variables such as the GRF, the time to peak GRF, reaction time, execution time, total response time and the peak velocity of the kicking foot in the roundhouse kick to the chest. The second aim of the study was to analyze the relationship between the GRF and kinematical variables in each of the three stance positions.

METHODS: Participants: Two high-level taekwondo athletes participated in this study (mean age, weight and height were 30.12 ± 2.08 years, 65.48 ± 18.34 kg and 1.73 ± 0.13 m).

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Instrumentation: Participants were standing on two 3-D force plates (Kistler 9286AA, Switzerland) (247 Hz), while kinematic data during the roundhouse kick were collected at 247 Hz with an eight-camera motion capture system (Qualisys Oqus, Sweden). A LED was placed on the target and all the equipment was synchronized.
Experimental design: During the test, each foot was positioned on the force plates. Before data collection, calibration and tracking, retro reflective markers were positioned bilaterally on each subject. Calibration markers were positioned on acromions, greater trochanters, medial and lateral femoral condyles, first and fifth metatarsal heads. Tracking markers were securely positioned to define pelvis (anterior superior iliac spines, posterior superior iliac spines, iliac crests), trunk (rigid triad), thighs (rigid arrays of four markers), shanks (rigid arrays of four markers) and feet (medial and lateral maleoli, calcaneus), all according to the recommendation of the C-motion Company (C-motion, Rockville, MD, USA). Each participant's preferred target distance was used as the execution distance (Kim et al., 2010), and they performed five kicks from each stance position. Each trial was started when the LED lit up. The stance position was established by three different oriented marks on the ground: three lines (0º, 45º and 90º) were prepared. Trials were randomized.
Analytical methods: Marker and force data were processed using Visual 3D software (C-motion, Rockville, MD, USA). All extremity segments were modeled as a frustum of right circular cones whilst the torso and pelvis were modeled as a cylinder. The variables of this study were: resultant ground reaction force (GRF) taking into account that in the initial position subjects were zeroed on the force plate; reaction time (time from when the LED switched on to the rear force plate overload reached 1% of the athlete's weight), peak GRF (time from when the rear force plate overload reached 1% of the athlete's weight to the peak GRF), execution time (time from when the rear force plate overload reached 1% of the athlete's weight to the target starts movement), total response time (sum of reaction time and execution time) and the peak velocity of the kicking foot (Vpeak). Preliminary analysis (Kolmogorov-Smirnov) did not show a normal distribution of the considered vararíables. Therefore, a non-parametric Kruskal Wallis test was used to compare mechanical variables according to the stance positions ($p < 0.05$). Mann-Whitney U test was used to analyze pairwise comparisons effect. Cohen's d score was quantified to analyze the effect size. Cohen considered that a d larger than 0.8 signified a large effect and a d between 0.8-0.4 signified a moderate effect (Cohen, 1988). A linear regression was used to assess the effect of GRF on velocity and time variables.

RESULTS: Statistical descriptions (mean and standard deviation) are shown in Table 1.

Table 1
Comparative analysis among three different stance positions in GRF and time variables

	0º stance position	45º stance position	90º stance position
	Mean ± SD	*Mean ± SD*	*Mean ± SD*
GRF (N)	913.17±165.33	1064.25±187.71	1053.05±321.32
Vpeak ($m{\cdot}s^{-1}$)	11.36±1.41	11.86±1.65	11.89±1.67
TGRFpeak (s)	0.149±0.022	0.182±0.042	0.226±0.047
RT (s)	0.230±0.062	0.204±0.050	0.225±0.075
ET (s)	0.505±0.030[a]	0.540±0.052[b]	0.600±0.056[ab]
TT (s)	0.734±0.052[a]	0.745±0.059[b]	0.824±0.098[ab]

Note: GRF = Ground reaction force. Vpeak = peak velocity of the kicking foot. TGRFpeak = period of time from 1% of GRF to the peak GRF. RT = period of time from when light switches on to 1% of GRF. ET = period of time from GRF (1%) to the impact. And TT = total response time or the sum of RT and ET or period of time from when light switches on to the impact. Similar letters to the right of the mean and *SD* value imply significant differences ($p < 0.05$).

According to Cohen's d score (Cohen, 1988), most of the differences we found can be estimated as large differences; only the difference in total response time between the 0º and the 90º position was moderate. Figure 1 shows the GRF in each of the three different stance positions.

Regression analysis showed that GRF at 0º, 45º and 90º explained 86.2% (β = 0.93), 93.7% (β = 0.97) and 87.5% (β = 0.94) of the variance of the peak velocity ($p < 0.01$), respectively. GRF at 45º and 90º explained 84.1% (β = -0.92; $p < 0.01$) and 57.8% (β = -0.76; $p < 0.01$) of the variance of the time to the peak GRF, respectively. Also, GRF at 45º and 90º explained 85.1% (β = 0.97) and 72.7% (β = 0.97) of the variance of the execution time ($p < 0.01$), respectively.

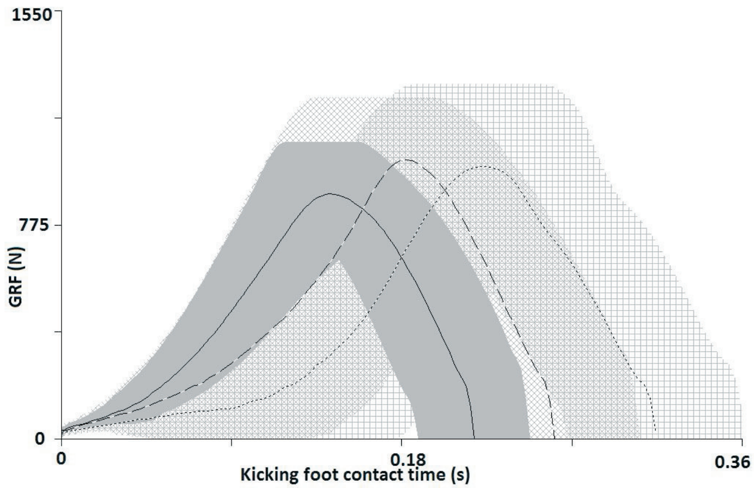

Figure 1: Mean and standard deviation of kicking foot magnitude of GRF [square root of (F_x^2+F_y^2+F_z^2)] from the three (0º, 45º and 90º) stance positions (n = 10, five kicks per athlete). The solid line represents the magnitude of GRF mean at 0º, the dashed line at 45º and the dotted line at 90º stance positions. The solid area represents standard deviation of magnitude of GRF at 0º, the diagonal crosshatch area at 45º and the vertical crosshatch at 90º stance positions.

DISCUSSION: This study aimed to compare mechanical variables such as GRF, time to peak GRF, reaction time, execution time, total response time and peak velocity in the roundhouse kick in taekwondo from three stance positions. To our knowledge, this is the first study that compares the mechanical performance according to the stance position in taekwondo. The results showed that regardless of the stance position, taekwondo athletes can react in the same time. However, in line with Kim et al. (2010), the results of our study showed that the stance position affects kick performance since at the 0º and 45º positions athletes generated similar GRF and kicked with less execution and total response time compared to the 90º position, which means a more appropriate execution (Estevan et al., in press). Moreover, our results are in line with Wang and Liu (2002), who stated that attacks in positions with a higher load on the front foot (i.e. the 0º and 45º stance positions of our study) were made with a faster movement than those attacks made with an equal load on both feet (i.e. the 90º stance position).

Whereas from the 45º and 90º stance positions a higher GRF means less time to reach the GRF peak and execution time, from the 0º onset position no correlation among these variables was found. From a tactical point of view in taekwondo combats, attacks and counterattacks are clearly important. The 45º and 90º stance positions seem to allow athletes to comfortably execute every type of kick (i.e. roundhouse, axe or back kick) whereas the 0º stance position does not seem to allow athletes to develop back kicks as appropiately as roundhouse kicks (athletes said that they were not comfortable), possibly due to an inadequate position to exert force in the lateral component direction.

Regarding the regression analysis of the mechanical data, regardless of stance position, GRF explained a high percentage of the peak velocity; that is, as more GRF is exerted, a

higher velocity can be gained in the kick. Moreover, GRF explained a percentage of the execution time but not the reaction time or the total response time; it seems that when mechanical analyses in taekwondo are done, the kick should be divided in several periods because it offers important information. Execution and different phases of the kick performance should be analyzed in-depth in future studies.
Although the roundhouse is the most frequent kick in taekwondo combats, it is also a complex and explosive motor task (Estevan et al., in press). In line with Fortier et al. (2005), our results showed that the kick start is characterized by large forces and by the ability to generate these forces in a short period of time. Thus, the results showed that independently of the stance position, taekwondo athletes can react in the same time and can also obtain the same peak velocity in the kick. From the 0º and 45º positions athletes kick in less time compared to the 90º position, and at the 45º and 90º positions a higher GRF means less execution time, but no relation was found at the 0º position. Thus, it seems that the 45º stance position could enhance sport performance. This could also have important implications from a tactical perspective. The 45º position allows athletes to do whichever technique they prefer, even back kicks. Also, this position enables the athletes to perform attack or counterattack kicks, which may be due to a better trunk orientation and means more adequate options to generate forces in the direction the athletes desire. However, future studies should analyze the mechanical performance of different types of kicks and in different contexts, such as attack or counterattack kicks in taekwondo. In addition, due to the small number of participants, the results of our study can not be generalized to the whole population. More studies with a higher number of athletes are needed before a conclusion can be drawn on the possible effect the stance position may have on kick performance.

CONCLUSION: This report presents novel scientific information in taekwondo. The stance position is a factor that affects the mechanical performance of taekwondo athletes' kicks. The 90º stance position involves longer execution and total time than the 0º and 45º stance positions in the roundhouse kick. The 0º and 45º stance positions seem more appropiate than the 90º stance position.

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